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AUTHOR Hedberg, John; And Others
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ABSTRACT

This paper describes research into the use of cognitive tools in the classroom using "Exploring the Nardoo", an information landscape designed to support student investigation. Simulations and support tools which allow multimedia reporting are embedded in the package and are supported by several metacognitive tools for the writing process. The tools include details about genre and also provide scaffolding templates to support the learners. "Exploring the Nardoo" provides a rich information landscape of resources based on ecology, with a Water Research Center and a navigable river environment. It incorporates problems that challenge students to become active participants in the learning process and simulators that allow the user to ask questions and investigate possible answers to those questions. By providing a metaphor relating to the real world, students are encouraged to apply scientific concepts and techniques in new and relevant situations throughout the problem-solving process. The package incorporates high quality visual materials in the form of graphics, sound, text, and motion video together with scientific measuring tools to aid in the construction of understanding. Experiences using the package with two groups of high school students (n=8 and 11) and future cognitive tool development are discussed. (Contains 12 references.) (Author/SWC)

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Employing Cognitive Tools within Interactive Multimedia Applications

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John Hedberg
Barry Harper
Robert Wright
University of Wollongong

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Abstract

This paper describes research into the use of cognitive tools in the classroom using Exploring the Nardoo, an information landscape designed to support student investigation. Simulations and support tools allow multimedia reporting and are supported by several metacognitive tools for the writing process, which provide scaffolding templates to support the learners.

Introduction

The introduction of information and telecommunication technology, and specifically computers, into the educative process has often been heralded as the new panacea for education. The technology offers teachers the opportunity to individualize instruction, place children in open ended student-centred investigations, and to shift from their traditional instructor role to mentor and co-learner. The panacea however, like past revolutions in education, will go the way of previous technologies unless there are changes to the cognitive tools provided within or supporting complex applications. Alfred Bork (1995) has argued in his critical review of the failure of computers in schools and universities that the effective use of new instructional paradigms requires:

- a shift in teachers' pedagogical approaches
- software that supports the modes of instruction that cognitive scientists are telling us are appropriate

One of the most extensive longitudinal studies on the effect of the introduction of information technology in classrooms has been carried out under the Apple Classroom of Tomorrow (ACOT) program (Dwyer, 1995). The ten year research and development collaborative program focused on how teaching and learning changed when teachers and students have routine access to technologies. One of the key elements of this program was a belief that technology should be used as a tool for learning and a medium for thinking, collaborating, and communicating. The outcomes of the program have been summarized by Dwyer (1995)

> ...technology plays a catalytic role in opening the minds of teachers to new ideas about children, learning, and their own role in the education process.

Dwyer also claims that without this form of reflection and subsequent changes in professional practice, the promise of technology will never be realized. This premise supports the criticisms of Bork (1995) and Schank and Cleary (1995) of our current modes of education.

Changing instructional strategies with Interactive Multimedia

Instructors have traditionally presented a linear narrative sequence which revealed the underlying structure of their ideas, based largely upon their understanding of the concepts, and their perception of the learning environments they have generated. However, learning environments in classrooms are affected by the behavior of teachers which are the outcomes of the beliefs and goals a teacher brings to the classroom (McRobbie and Tobin, 1995). So too do the beliefs of students result in a diverse set of perceptions of the classroom learning environment (Roth & Roychoudhury, 1992). Ritchie et al (1995) have found, in exploring the boundaries of learning environments in a science classroom, that individuals and groups experienced different learning environments and that the actions of students and their teacher could be explained in terms of their beliefs, roles, goals and behaviors in various activity settings.

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Current interactive multimedia technologies can represent ideas in almost any mediated form, and provided we can generate a comprehensible metaphor for organizing our functional options and the underlying knowledge structures, the student can roam through the resources, creating their own meanings and understandings of the phenomena they encounter, ie creating their own form of the learning environment rather than one generated by their teacher or by the package designer. With graphical and visual display coupled with large databases of resources, it is possible to explore an information space in whatever sequence appeals as appropriate to the user or to the specific task. When raising the idea Florin (1990, p30) saw information landscapes, ...as virtual towns, or intellectual amusement parks. The analogy is quite intriguing and helps us to visualize many abstract concepts within a single metaphor.

This form of representation of information supports students' learning processes advocated by researchers like Schank and Cleary (1995) who have argued strongly for the use of such technology to support students in following their own interests or questions. This rich context has the potential to allow the novice to work with authentic problems and practice.

However, within this context, designers of multimedia learning environments have tended to be narrow in their view of how users will interact with the rich array of multimedia resources once a challenge, in the form of a problem to solve, has been posed. Instructional designers have not often taken full advantage of the technology that is being used to present these powerful ideas. Once the material has been presented to user(s) and they have interacted in the ways envisaged by the instructional designer (and often in new ways not considered by the designer) the user is left to ponder and present their conclusions using more routine presentation technologies, such as pen and paper. Increasingly, users have access to the same multimedia technology but have lacked access to the rich digital media resources embedded in the learning environment.

As new theoretical views of learning have developed, it has been recognized that learners act as active constructors of knowledge (Duffy and Jonassen, 1992). Within this constructivist framework, which is concerned with the process of how we construct meanings of our world as well as with the results of the constructive process, cognitive tools can help learners organize, restructure and represent what they know. Jonassen and Reeves (1996) have summarized the foundations of cognitive tools research and have identified the following key principles in the context of multimedia design:

- Cognitive tools will have their greatest effectiveness when they are applied to constructivist learning environments.
- Cognitive tools empower learners to design their own representations of knowledge rather than absorbing knowledge representations preconceived by others.
- Ideally, tasks or problems for the application of cognitive tools should be situated in realistic contexts with results that are personally meaningful for learners. (p. 698)

Additionally cognitive tools to support the user have been shown by Jonassen (1995) and others to enhance the learning process and to support the users' investigations. If students are to truly create their own meanings and understandings of the phenomena they encounter, designers need to not only incorporate user tools which will enable them to present their findings using the full array of resources contained in the packages, but also support their investigations with powerful cognitive tools.

The lack of powerful learning environments embedded in much of the interactive multimedia products currently available cannot be entirely attributed to the lack of understanding of the results of cognitive science research by developers. The challenge for researchers is to not only conceptualize powerful learning environments, but also demonstrate that process so that developers of educational software produce products that support learning in the most effective ways rather than predetermine the learners' needs, interests and preferred learning styles. This use of information technology offers the opportunity to shift the learning to student driven and directed learning.

Supporting learning with Cognitive Tools

Cognitive scientists are attempting to narrow the gap between the learning environments portrayed in many commercial interactive multimedia packages and learning environments that will truly enhance learning. Schank and Cleary (1995) have described a set of innovative learning architectures based on their conceptualization of realistic learning situations. These powerful packages illustrate the lessons of cognitive science research through:

- Simulation-Based Learning by Doing
- Incidental Learning
- Learning by Reflection
- Case-Based Teaching and
- Learning by Exploring

Each of these teaching architectures have been illustrated with specific packages such as *Dustin*, a simulator designed to help a student learn a foreign language, *Road Trip:* The Geography Un-Lesson, *Sounding Board*, a package to bounce ideas off, *Creanimate* Project, a case-based package for designing/creating animals and *ASK* System, a form of hypermedia based on the metaphor of having a conversation with an expert. The software technologies discussed by Schank and Cleary (1995) create powerful example implementations of cognitive tools where different cognitive learning strategies are built into software and the learner is encouraged to explore their ideas and solutions with differing degrees of support and advice.

The innovative use of cognitive tools in interactive multimedia learning environments has also been reported by Lajoie and Greer (1995). The package Bio-World (Lajoie, 1993) is an interactive learning environment designed to support the acquisition of scientific reasoning skills in high school students and integrates a variety of cognitive tools to assist in scaffolding scientific reasoning activity. Users of this package are engaged in explicitly justifying hypotheses with evidence; organizing, categorizing, and rating evidence; and constructing a final summary argument on the topic of bacterial and viral infections. A proposed development for this package incorporates an authoring mode for students to generate new scenarios for their peers to investigate, this in turn, will support the powerful augmentation framework design of the package.

Exploring the Nardoo with student driven investigations

With an understanding of the shortcomings of much of the commercially generated learning packages, we sought to combine the ideas of situated learning and problem based learning from rich information landscapes to form the basis for effective design. Within this context we also sought to incorporate a range of cognitive tools within the landscape which would contribute to supporting the learner. The detail of this design process and the theoretical position has been reported in Hedberg et. al. (1994). The resulting package, *Exploring the Nardoo*, provided a rich information landscape of resources based on ecology. The information landscape uses a geographic metaphor based upon a Water Research Center and a navigable river environment. It incorporates problems that challenge students to become active participants in the learning process and simulators that allow the user to ask questions and investigate possible answers to those questions. By providing a metaphor relating to the real world, students are encouraged to apply scientific concepts and techniques in new and relevant situations in this ecology-based application, throughout the problem-solving process. In so doing, the learner is likely to become more interested in developing questions, ideas and hypotheses about the learning experiences encountered. As an alternative teaching/learning strategy in the development of inquiry and problem solving techniques, this package incorporates high quality visual materials in the form of graphics, sound, text and motion video together with scientific measuring tools to aid in the construction of understanding. *Exploring the Nardoo* provides the student with a flexible set of tools made available through a personal digital assistant (PDA), Figure 1, to assist in the investigation process.

Figure 1. The Personal Digital Assistant

Figure 2. Water Management Simulator Notebook

The process of using source material within the package in support of an investigation has been enhanced to allow the student to:

- Decide precisely on the quantity and selection of text to be copied into their notes. This is either through making a selection and then 'grabbing' it into the PDA or by using a 'drag and drop' technique where the target text is selected or highlighted and 'dragged' into the notes module of the PDA .

- Use marker buttons as pointers to video, audio or picture information which can be displayed within the PDA's viewer along with any linked information. For example, by copying a picture of a wombat into their notes, the student is able to move through the information landscape in the package and very quickly view the picture of the wombat as well as its associated text in the PDA's viewer merely by clicking on the marker button within their notes. User defined portions of the reference text material displayed within the viewer may be selected and copied into the notes also.

- Manipulate marker buttons and text within the notes areas, via 'drag and drop', to facilitate the re-ordering of ideas in the process of building an investigative response in the form of a report, explanation, procedure etc.

- Use text style tools, within editable text notes, providing the opportunity to use font color, style and size as organizing criteria within the notes. For example a student may recognize that a certain combination of text attributes is representative of newspaper clippings or they may choose to color information they write or gather from a particular perspective in a special color.

The joint combination of note book and viewer equips students to view and then critically evaluate or compare different representations of the same information concept. By collecting different media representations of the same topic and 'flipping' between these representations at their discretion, the student has the opportunity to

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establish cognitive links between different media forms which complement each other and support a central theme or information focus.

The package also provides the ability to record thoughts and impressions 'on-the-fly' whilst examining media stories. This provides the potential for students to reorganize or revise their thoughts to better 'make sense' of what they see and hear. Students are able to document their emerging ideas in support of an investigation or problem solving exercise whilst viewing different media. This provides support in the formulation of new schemata in the process of accommodating the new information.

By way of illustration, whilst viewing a video segment related to the issue of water conservation, students may have their attention drawn to a specific aspect such as better ways to manage water use within the household. The *Exploring the Nardoo* PDA provides the means by which they are able to search out other related information (text, graphics, radio/television reports) and store it within their notes 'alongside' previously captured information. The different perspectives represented within the source media items can be viewed, edited and brought into context within the student's framework of notes they are making.

Successful problem solving activities are reliant on numerous individual, social and environmental factors. From a technique perspective, *Exploring the Nardoo* endeavors to assist students by providing some structures, or templates, upon which they can build their note taking or response writing activities. These are in the form of writing genre templates. Students may access the book containing these templates (as well as other organizational help on note taking, presenting and filing) from within the Water Research Center - a metaphor within the information landscape of the package. Genre descriptions can be viewed and a genre template can be copied into the notes and used as a scaffold upon which to build or fill-in relevant information found whilst exploring the package.

To facilitate the re-ordering or re-prioritizing of information *Exploring the Nardoo* provides a separate, expanded form of the notebook. This device has been termed a 'text tablet'. It provides the editing facilities offered by the PDA as well as other features to assist with the restructuring of notes into a form more suited to small group presentation or a particular genre style. The text tablet provides a larger expanse of editable screen/document space into which student notes may be copied to/from the PDA notes module.

A writing genre template (discussed in the following section) can also be loaded directly into the text tablet into which portions of the student's notes may be copied or dragged. Notes from prior sessions can be loaded into the text tablet and used in support of current investigations. Being able to store and report thoughts and impressions derived from media experiences by using the media itself (actual video/audio and pictures, not just text representations of the media) provides a more powerful means of 'reformulating' (Schroeder & Kenny, 1994, p 965) ideas.

The multimedia collection, editing and presentation facilities offered within *Exploring the Nardoo* are extensive and present a great potential for students to become manipulators of multiple media. New avenues are opened for expression for those who choose to use the facilities within the package. We are aware however, as Schroeder and Kenny (1994) point out "learner's not accustomed to this technique and multimedia facilities will require instruction in its use" before they become proficient with the technique but once accustomed to it the student has a powerful process at their disposal to gather, organize and illustrate their ideas. Support for teachers and students in the use of these features has been modeled using walk-through movies made available through the help system and also detailed in support notes available in reference books within the package.

Specialized support tools for exploration

Exploring the Nardoo contains two specialized tools aimed at providing support at a deeper level for the exploration process, namely, three interactive simulations and a presentation guide which, together with support for note taking methods and suggestions on filing of materials, contains a series of genre templates.

The three simulations available in *Exploring the Nardoo* are, an algal bloom simulation, a whole catchment level, water demand management simulation and a personal, home based water use simulator. Each of these simulations is a powerful exploratory tool, which provides support for the solution to one of the embedded problems by mimicking a 'real world process' which forms an integral part of one of the problems encountered in the Nardoo River Catchment. They greatly enrich the 'quality' of the problem solving process for students by providing the student with unhindered access to act and become immersed in a 'real' situated process, manipulating the various causal parameters and testing hypotheses without a 'real' consequence or risk and in a time frame which is convenient to them. (Figure 2)

They promote the adoption by the student of the active learner mode and in so doing support the active construction of knowledge by the student during the process of solving a problem. The simulations complement the

problems embedded in a complex information landscape by providing links with the 'real world' experience and by creating an environment in which the user may practise skills.

More able students are provided with the facility to solve problems at a deeper level through the testing of their own "what if" scenarios. This can, during the course of solving problems, facilitate more detailed exploration and learning by:

- allowing the user to take readings at a site which they use as inputs for the simulation studying the changes as the simulation runs,
- allowing the monitoring of all parameters while the simulation is running, with the aim of exploring the relationships between them (Corderoy, Harper & Hedberg, 1993, p 126)

A necessary skill in problem solving is the ability to collect and manipulate and analyze many different forms of data and then present them in a meaningful and useful way to any of the many different discourse communities. The genre template tool in the presentation guide provides a suitable mechanism for the support and development of this skill.

The student support for the collection of this data in the form of note taking and the resulting solutions to problems needs to include modeling of the various styles of discourse used in different communities.

The use of the notebook metaphor can be carried through to the creation of multimedia presentations. The notebook can be used as an organizer for drafting the presentation and should make the transition to a finished multimedia product seamless. Templates such as the genre templates within a notebook can be used as advanced organizers for the learner, especially those with little prior knowledge. The templates also provide a framework for gathering information and stimulating recall of prior knowledge.

By making such templates available and encouraging their use, we are assisting students through a modeled form of outlining. Identifying concepts within their notes that bear some relationship to part of a template structure requires high order thinking skills which "a) causes focusing on important points, b) helps students gain familiarity with text structure, c) aids retention, d) generates useful alternative texts to supplement materials read, and e) causes active participation in learning (Bianco and McCormick, 1989 in Schroeder & Kenny, 1994, p966) The value of this modeling process is not faculty, learning style, level of school, or type of writing dependent.

The development by an individual of genre-specific schemata can have a number of generative and empowering consequences, the most significant of which is the development of the ability to communicate more effectively with a wider spectrum of the community by producing better responses to problems.

Researching the cognitive tool use by students

To investigate the use of these tools by students a series of data gathering methods were employed. Two groups of students (n= 8 and 11) from a local high school were organized to attend a work session where they followed the procedure below.

1. Students were given a short introduction and orientation to the staff present and the facilities they were going to use.
2. A demonstration of the package was provided using a large projected display on which all visual and auditory clues could be seen and heard clearly. At this development stage, it was not possible to have an in-built "Help" facility within the package, the demonstration covered a basic walk-through of the package showing...
   - a representative sample of accessing information in different areas leaving sufficient room for student exploration and experimentation. (eg in the Water Research Center students were shown how to activate a 'hot-spot' and 'zoom-in' to view a Plant and Animal Book; in a region of the river environment students were shown how to activate the tools module to measure embedded environmental data and also how to gather an embedded media article.)
   - ways of navigating around the package
   - general operation of the Personal Digital Assistant (PDA).
3. The students were introduced to the survey form which they were asked to complete during and after the use of the software. All questions were answered. The survey was aimed at the functionality of the different program elements with specific attention being paid to the Personal Digital Assistant.
   - Questions were brief with ample room and encouragement for individual comments or general reactions to the program.

- Direction was given within the survey to spend about 20 mins using the facilities within the Water Research Centre and the remainder (approximately 25-30 mins) investigating a problem.
- Students were encouraged to write any other comments they may have had about their experience that fell outside the questions on the form.

4. The students were then asked to work in pairs and in some cases a group of three (this sort of collaboration is encouraged in working with this program). As a team students worked their way through the worksheet/survey at their own pace.
5. During the activity the teacher, the researcher and other staff moved about providing assistance if requested and making observations as to how the package was being used.
6. At the conclusion of the allocated time, the students were once more, either in their small work group or together as a unit, able to express impressions, concerns, praise etc arising from the session.
7. The class teacher was given opportunity to review the written responses of the students and to give some context to them relative to the 'perceived' way in which he thought the students may or may not have reacted to the activity.

Results

One of the most obvious results that had a direct influence on the direction and scope of this investigation, was the need for students to become familiar with the package and how it functioned before they are able to attempt to develop a response to an investigation. In the time allocated students did not seem comfortable enough with the facilities or general concept of the package to become seriously involved in using the multimedia editing tools to edit their work. Most of their time was spent exploring and gathering resources — this process was lengthened as they were simultaneously completing the survey form. The students were able to focus more on investigating an issue when they were familiar with the package and more resources were embedded. This was an indication of the high level of intuitive functionality that the package possessed. This investigation is continuing.

This research study also identified the need for more specific details about how each program element functions and for clearer statements of what problem solving strategy should be selected and how it might have been implemented in response to an embedded investigation problem. These issues have largely been addressed through the visual modelling of processes and tool functions by 'walk-through' movies in the 'Help' system of the package

From the package description above and the data gathering activities, the level of successful problem solving relied heavily the functionality of the visual images and pseudo–measuring devices. It was also apparent that until the package was fully resourced in terms of 'Help' and data gathering/organising features, the use of the tools for report generation or idea re-organisation required substantial support external to the software. It was apparent that students would probably need to seek assistance from their teacher when using a program of such density of information provision. However, some problem solving help would overcome widely varying levels of teacher expertise. Some questions that will be investigated in the future include:

- Now the program is fully resourced and functioning intuitively, the level of acceptability of the interface and degree of difficulty students encounter when using the editing and presentation tools will be assessed.
- Video and audio recording of test subjects with subsequent transcription and analysis of the sessions will enable a more detailed analysis.
- Students will be asked to draw a concept map (bubbles, boxes, labels and arrows) to represent their perception of what the package contains and any interrelationships that exist at the end of their session of working with the materials.

Some ideas have been gathered and already implemented as a result of the data gathered. For example, a more easily identified button on the Personal Digital Assistant to access the note-editing tools, and clearer direction when developing necessary instructions for using the simulator and text tablets. Favourable comments have been received about the functionality of most of the resources within the Package. Observations revealed that not all students realised that the clipboards could be used to access video and radio material, and could be viewed in the Personal Digital Assistant viewer by clicking on the highlighted line of text which described a particular media item. Some students just read the text and turned the pages. This indicates the need for further instruction on the clipboard. The need for a clear demonstration showing investigative activity and appropriate problem solving within the package is still required.

Future Cognitive Tool Development

The outcomes of the research so far suggest that the cognitive tools designed to support Exploring the Nardoo, have the potential to support learners in the quest for meaning and understanding. However, it is anticipated that a range of further tools could extend the support for users. For example, the work by Ferry (1996) has shown that cognitive tools with a semantic emphasis can be used effectively to represent the developing knowledge of learners. His concept mapping tools have shown the potential to support learners in structuring and representing their ideas. *Exploring the Nardoo* currently contains cognitive tools that allow users to represent their ideas in multimedia format, but only in a linear form. A concept mapping tool which enabled non-linear relationships to be represented would help students to constuct a more complete and visual representation of their ideas.

Other tools that will now be investigated include:

- Resource collection tools that enable the collection of any visual representation format: verbal, data, graphics or temporal (through Quicktime movies)
- Conversion tools that enable changing of information from one representation form into another,either by making notes or the permanent link between a visual representation and its textual description
- Oganising tools to enable different representations of the problem solution
- Scaffolding tools that anable students to organise their concepts into a logical structure which might depend upon the form into which knowledge is to be transformed.

Conclusion

The development of innovative interactive multimedia packages that support student driven exploration and investigation has not been a priority for the multimedia industry. Design models and examples of such products are now being presented by researchers to not only support the research endeavour in this field, but also to support more commercial design of educational products. *Exploring the Nardoo* is an example of a product which provides a range of cognitive tools in an information landscape to support student investigation. Simulations and support tools which allow multimedia reporting are embedded in the package and are supported by several metacognitive tools for the writing process. These tools not only include details about genre but also scaffolding templates to support the learners. The extent to which problem solving and student centred learning goals are achieved will be investigated and reported upon as the use of the product within schools becomes more widespread.

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Authors

John Hedberg, Barry Harper, and Robert Wright research within the Interactive Multimedia Learning Laboratory, Faculty of Education, and Bob Corderoy is a postgraduate student in the Laboratory and works with Educational Media Services at the University of Wollongong. Correspondence should be addressed to Dr. John G Hedberg, Associate Professor and Head, Graduate School of Education, Faculty of Education, University of Wollongong, Wollongong NSW 2522, Australia. email: John_Hedberg@uow.edu.au